ROYAL ASTRONOMICAL SOCIETY.

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Rev. BADEN POWELL, V.P., in the Chair.

John Robinson Maclean, Esq., 17 Great George Street;
Col. Baron de Rottenburg, C.B., Toronto, Upper Canada;
Chas. V. Walker, Esq., Redhill; and
Nathaniel Beardmore, Esq., 30 Great George Street,

were balloted for and duly elected Fellows of the Society.

The Council desire to make known to Directors of Foreign Observatories, and to other persons who may have claims to the work, that they have still in stock several copies of Mr. Johnson's *St. Helena Catalogue of Southern Stars.* Applications to be addressed to the Secretaries.

New Comet.

(Letter from W. C. Bond, Esq. Director of the Observatory of Harvard College, to Mr. Carrington.)

"A faint comet was discovered here in the evening of the 4th instant at $7^h\ 30^m$ P.M., by Mr. H. P. Tuttle.

"The following places of it have been obtained:—

1858.	Camb. M.S.T. h m s	Comet's Ap. R.A. h m s	Comet's Ap. Decl. ° ′ ″
Jan. 4	9 31 55·8	23 42 30·30	+ 39 41 9·1
7	7 21 14·9	23 55 45·43	+ 37 3 33·2
8	7 18 23·6	0 0 16·58	+ 3 6 47·0

Observatory of Harvard College, Cambridge, U.S.
Jan. 11th, 1858.

Previous to the arrival of the intelligence of Mr. Tuttle's discovery in Europe, the comet was discovered by Dr. Bruhns at Berlin on the 11th of January.

The following approximate position was obtained:—

$9^h\ 2c^m$ M.T. Berlin.

R.A. $0^h\ 53^m$ N.P.D. 64° 40′

On the Measurement of the Position-Angles of Double-Stars with the Divided-glass Double-image Micrometer. By the Rev. W. R. Dawes.

The usual method of measuring the position-angle of a double-star with a double-image micrometer, is by bringing the four stars composing the two images into a line, the components being placed at equal distances, whereby the double distance and the reading for position are obtained at the same time. The angle may thus be measured with considerable accuracy, *provided the images are round and well defined*, as in the double-image *crystal* micrometer, where the separation of the images is produced by the principle of double refraction in the crystal. Yet even in this, I believe that a more certain mode may be employed. But where the duplicity of the image is produced by the division of a lens, and, consequently, each of the images is formed by only one-half of the object-glass, the distortion of the image is so great (increased in bright stars by the coloured fringes in opposite directions) that, lying as it does at right angles to the direction of separation, a really accurate measure of the position-angle is impossible; and nearly all that can be hoped for is to place the images with sufficient correctness for measuring the double distance. This forms so serious a drawback to the use of such an instrument in double-star observations, that a statement of a method of observation by which the difficulty may be completely removed, and which I have satisfactorily employed for more than two years, will not, I trust, be unacceptable to the Society.

My plan is this: Two very fine wires, or very stout spider's webs, are placed parallel to each other, with their interior edges at a convenient distance apart (about eight or ten seconds) in the focus of the eye-glass or positive eye-piece. These are intended for the measurement of position-angles, by placing the stars

between them. They are either fixed by the maker *at right angles to the direction in which the images are separated by the micrometer;* or the eye-piece is so arranged that they may be brought into that position by the observer. Their direction is then *parallel* to that of the elongation of the images by diffraction.

In the application of these parallel wires to the measurement of position, the image is to be made *single*, by placing the index of distance at the zero-point, which may be known precisely if the distance has been first measured. This single image is then placed between the parallel wires for the measurement of the position-angle; the zero of position being obtained by causing the star to run along one of the wires.

If the star is bright, even the *single* image will not be free from appendages which would be annoying, and seriously detrimental to the accuracy of the observation, were the wires in any other relative position than that above described. But when they are so placed, the bright ray which crosses the image of a bright star is *precisely parallel to the wires:* and when, by turning the position-circle, their direction is brought to coincide with the position of the double star, the ray is not only parallel to the wires, but *also passes through the centres of the two stars*, and therefore in no degree prejudices the judgment of the eye in the measurement of the position. From numerous measures thus obtained, my conclusion is, that the results are equal in accuracy to those with the ordinary parallel-wire micrometer.

As it is of some importance that the double webs or wires should be pretty exactly at right angles to the direction of the separation of the images, it may not be superfluous to mention a process by which this may be readily accomplished by the observer. The parallel wires should be attached to a diaphragm turning along with the eye-lens in a four-glass eye-piece, or with the double eye-piece in the Amician form, and also fixable in the required position by a tightening screw or clamp. The rule will then be: Separate to a considerable distance the two images of any star of suitable magnitude (which may conveniently be pretty near the equator), and turn the wires in the eye-piece till the two images of the star are threaded upon one of them. Then turn the whole micrometer on the position-circle till the images run along the wire by the diurnal motion. Note the reading of the position circle, and then alter it 90° either way; also bring the two images into one. Turn the wires in the eye-piece, without altering the reading of the position-circle, till the single image is again carried along one of the wires by the diurnal motion; and the direction of the wires will then be at right angles to the direction of the separation of the images. The wires being clamped in that position will remain ready for use in this mode of observing.

In the directions above given, it is assumed that the two images pass each other *centrally*. If they do not, they should be made to do so by a slight alteration of the focal adjustment. The correctness of the adjustment for this purpose may be judged of

by noting whether both images of a single star continue to be threaded on one of the wires, while one image is carried across the other; the separation on either side being considerable for greater accuracy. This adjustment should be attended to before entering on the process above described for placing the wires perpendicular to the direction of separation.

If, however, the observer would rather have *round* images to deal with, they may be obtained by a very simple process. A piece of card-board is to be prepared, in which have been cut *two circular apertures*, the diameter of each being equal to the radius of the object-glass. They consequently touch in the centre. Place this before the object-glass. Then, the imaginary line joining their centres being placed nearly at right angles to the approximately known position of a double star, the images will be perfectly round when brought into a line for the measurement of the double distance. The position-angle may therefore be observed at the same time by thus placing the stars, or by bringing them between the parallel wires, which should be fixed, for *this* mode of observing, *in the direction* of the separation. A comparison of the results obtained by these two very different modes of measuring the position-angle is not without interest. Having for many years practised both methods with the double-refracting crystal micrometer, in which the images are free from distortion, I have come to the conclusion that the most correct results are obtained by the parallel wires; and my observations with the Amician double-image micrometer, in the mode last described, look the same way. This is especially the case where the components of a double star are very unequal in magnitude.

It is obvious that the use of the two circular apertures diminishes the light from each section of the object-glass by one-half. If, however, the object-glass is of considerable size, the objection will not apply to the *brighter* double stars, and it is in these especially that the distortion and colour are annoying and productive of uncertainty. Where the object is too faint to permit this sacrifice of light, the first method proposed will be more advantageously applicable than the second.

An effect very similar to that produced by the two circular apertures, attends the use of an *elliptic* aperture, the major axis being equal to the diameter, and the minor axis to the radius, of the object-glass. The major axis being placed perpendicular to the direction of separation, the disks in each image will be sensibly round. In this case also the area in use is equal to half the area of the object-glass; and I am not aware that it possesses any advantage over the two circular apertures.

As a specimen of the results which may be procured by thus using the divided-glass double-image micrometer, I here subjoin the observations of γ *Virginis*, which I obtained with it during the last apparition, and also the results separately of each mode of varying the aperture; and, for comparison, add also those procured with the parallel-wire micrometer.

Measurements of γ Virginis with the Amici double-image micrometer.

Epoch.	Pos.	Obs.	Wt.	Dist.	Obs.	Wt.	Power.	Extr. Diff.
	°			″				°
1857·297	170·77	10	48	3·646	10	48	431	0·9
·338	170·48	5	27	3·560	10	42	431	0·6
·349	170·32	5	28	3·596	10	51	431	0·6
·351	169·36	5	32	3·601	10	61	252	0·4
·365	170·04	5	26	3·560	10	41	252	0·4
·371	169·98	5	40	3·549	10	44	252	0·5
·373	169·80	10	76	3·575	10	55	252	0·9

Remarks.

Epoch.
1857·297. Whole aperture. Air tolerably good.
·338. ,, Air bad.
·349. ,, Air bad.
·351. Double circular aperture. Air bad.
·365. Elliptic aperture. Air tolerable.
·371. Double circular aperture. Air pretty good.
·373. Double circ. app. for pos.; elliptic for dist. (placed parallel to pos.). Air pretty good.

The mean result of the whole is,

1857·35; P = 170°·08; obs. 45; wt. 277 on 7 nights:
D = 3″·586; obs. 70; wt. 342; on 7 nights.

The mean result of the observations in which the *whole aperture* was employed, is—

1857·32; P = 170°·57; obs. 20; wt. 103; on 3 nights:
D = 3″·600; obs. 30; wt. 141; on 3 nights.

With the *double circular aperture*, the mean result is—

1857·37; P = 169°·78; obs. 20; wt. 148; on 3 nights:
D = 3″·583; obs. 20; wt. 105; on 2 nights.

With the *elliptic aperture*, the result is—

1857·36; P = 170°·04; obs. 5; wt. 26; on 1 night:
D = 3″·569; obs. 20; wt. 96; on 2 nights.

This analysis of the results seems to show that the different kinds of aperture employed are not likely to introduce any perceptible difference in the measurement of either the angle of position or the distance.

The following results, procured with the parallel-wire micrometer, furnish an interesting comparison:—

Epoch.	Pos.	Obs.	Wt.	Dist.	Obs.	Wt.	Power.	Extr. Diff.
	°			"				°
1857·288	170·08	10	34	3·543	6	15	411	1·58
·294	169·85	10	40	3·613	6	18	411	0·85
·401	169·99	10	85	3·591	10	84	411	0·84
·445	169·91	10	69	3·581	10	45	411	0·35
·472	169·76	10	89	3·533	10	93	411	0·63
·477	170·04	10	77	3·541	10	72	526	0·52
Mean = 1857·42	169·93	60	394	3·561	52	327	On 6 nights.	

Remarks.

Epoch.
1857·288. Air bad.
·294. Ditto.
·401. Air very fine.
Epoch.
1857·445. Air pretty good.
·472. Air very fine.
·477. Air pretty good.

From a comparison of the numbers in the last columns of the two series of observations, it appears that the extreme differences among the angles measured on each night with the double-image micrometer, are not greater than those which occurred with the parallel-wire micrometer. But the extreme difference among the mean results with the double-image amounts to 1°·41; while with the parallel-wire it is only 0°·32: which may, perhaps, arise principally from the fact, that the sets taken with the latter consisted uniformly of *ten* observations, but with the former of only *five* on five nights out of the seven; and also that the state of the atmosphere was usually much more favourable on the nights when the parallel-wire micrometer was employed.

It is obvious that the same effect which is produced by a double circular, or figure-of-eight, aperture placed in front of the object-glass, may be secured by prefixing a diaphragm *before the micrometer*, and attached to it, so that it may turn with it in position. If a diaphragm so placed has two circular apertures whose circumferences touch each other in a point coinciding with the line of collimation of the telescope, and the diameter of each aperture is exactly equal to the semi-diameter of the cone of rays at the distance of the diaphragm from the focal point of the object-glass, the same quantity of light will reach the eye, and the images will be round and neat. This plan has the advantage that the line joining the centres of the two apertures, when once set perpendicular to the line of separation of the images, preserves that position by turning with the micrometer; while the apertures placed in front of the object-glass would require to be altered to a

position perpendicular to that of each double star observed, before the observations are begun. But, on the other hand, the diameter of the apertures in the small diaphragm prefixed to the micrometer ought to be very accurately proportioned, and the object must be kept very exactly in the centre of the field; otherwise, a portion of the light from the object-glass will be lost, and the images will not be perfectly round. Moreover, if the wires in the field are employed for measuring the angle of position, it will be found difficult pleasantly to illuminate them by the ordinary mode of reflexion from a diagonal plate in the telescope.

It would not be difficult to arrange a revolving aperture-plate within a brass dew-cap, the edge of the plate being toothed, and a pinion working in it; and a long light handle extending down the telescope tube would enable the observer to turn it at pleasure. The eye-piece being removed, the position of the apertures in the plate can be seen from the eye-end.

As it is often essential, in the measurement of delicate double stars (especially of close and very unequal ones, such as ζ *Herculis* and δ *Cygni*) to have a very accurate adjustment of the focus, I prefer securing this advantage, even though in so doing the central passing of the images should be somewhat disturbed. When this is the case, however, the readings of the position circle should be noted at which the two images are brought into a line on each side of the zero of distance, and the observed double distance must be multiplied by the secant of half the difference of the two readings.

As the double-image micrometer contrived by Professor *Amici* is not, I believe, much known in this country, it may be well to state, that in it the rays from the object-glass are received by the divided concave glass of the micrometer *before* they meet at the focal point.

Haddenham, Thame, September, 1857.

At the close of the reading of Mr. Dawes' paper, Mr. Main, at the request of the President, made a few remarks on the use of the double-image micrometer, and a conversation on the same subject afterwards ensued, in which Mr. De La Rue and Mr. Carrington took part.

New Planet.

A communication has been received from the Imperial Observatory, Paris, containing the announcement of the discovery of a new minor planet (the 51st of the group) on the 22d of January, by M. Laurent, at the Observatory of Nismes.

On the 22d of January, at 14 hours, it had the same right ascension as the star 22646 of Lalande, and was estimated to be 15′ further south, whence it would have a right ascension of

$11^h\,55^m\,43^s{\cdot}5$, and a declination equal to $4°\ 13'\ 30''$. On the 23d, the unfavourable state of the weather precluded the possibility of observing it. On the 24th, at $16^h\ 2^m$, it followed the same star, at a distance of 37^s, and was estimated to be $18'$ further south. At 18^h it followed the star at a distance of $38^s{\cdot}5$.

Notice of an Improvement in the Double-Image Position Micrometer. By William Simms, Jun. Esq.

The Rev. Mr. Dawes having at the last meeting made a communication containing some suggestions relative to the obtaining better angles of position than have been hitherto procured with the divided eye-glass double-image micrometer, and as I was engaged at the time upon the construction of one for Mr. Lassell, I have been induced to give some attention to the subject.

It will be remembered that the Astronomer Royal, when explaining his construction of the instrument, mentioned the difficulty of obtaining good angles of position on account of the elliptic images caused by the transmission of the pencil of rays through segments of circles; but that distances were measurable with extreme accuracy, the form of the star being favourable to this observation.

A suggestion having been made at the meeting that Mr. Dawes' plan of fixing, in front of the object-glass, a cap with two circular apertures in contact, might possibly be improved upon; it occurred to me, that the desired improvement would be effected if stops, with circular apertures of suitable diameters, and with their circumference just in contact, the point of contact being over the division of the concave lens, were made to slide into the micrometer itself, as near as practicable to the point where the rays cross to form the image.*

Upon trial, this was found to answer, the form of the star being decidedly improved, but of course with the same sacrifice of light as in Mr. Dawes' contrivance.

With planets, and other faint objects, I believe there would be no advantage gained in employing the stops, but the manner in which they may be removed, or changed, I consider to be much more convenient than any other method of producing the same effect.

In the instrument made for Mr. Lassell, there are four stops to accompany the four first lenses, numbered from 1 to 4, but any one can be used with any other lens, a smaller aperture stop being equivalent to cutting off some of the outer edge of the speculum or object-glass.

* Mr. De la Rue, in an instrument constructed for him, had shutters to slide in at the place, to regulate the brightness of one of the images.

On a New Artificial Horizon.

(Extract of a Letter from Professor C. Piazzi Smyth, Astronomer Royal for Scotland, to Professor Baden Powell.)

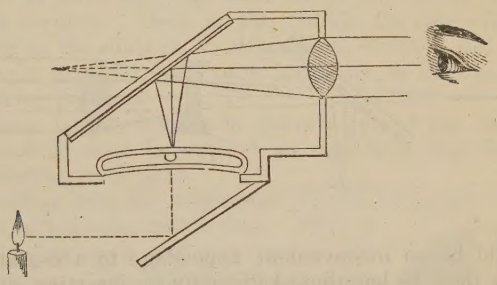
After adverting to the use of the spirit-level for adjustment of astronomical instruments on land, Professor C. P. Smyth observes :—

"On shore nothing can be more convenient than this use of the level; but its adaptation to sea service is not easy. For, first, on account of the constant movement of the vesssel,—never for the one-thousandth of a second stationary—we cannot first adjust the level and then look at the star, but must see both the star and the level simultaneously in the field of the telescope. Let us accomplish this before going into further and residual difficulties.

"The sextant or angular measurer at sea is made to allow of two objects being seen at once, the star, and the referring point at a great or infinite distance, usually the horizon of the sea, but in the present case the level-bubble is to take place of the horizon.

"We must therefore, 1st, put it at an infinite distance by means of a collimator; 2d, have it to be looked at in a horizontal direction, and 3d, have the bubble something very notable.

"Here (see diagram) a level is illuminated by artificial light thrown through it from below; above is a diagonal mirror, and in



front a lens in whose solar focus the bubble is. An eye therefore in front sees the bubble in the horizontal direction, at an infinite distance, and very visibly, because where the fluid curls up to form the edge of the bubble, it scatters the upward light so completely that none reaches the eye, and the bubble looks as if it had a painted black margin.

"If we place the eye partly in front of the collimator, and partly off, we may of course see both the level-bubble and something else; and in sextant observations may, by moving the proper mirror, see a star and the level-bubble in the field together.

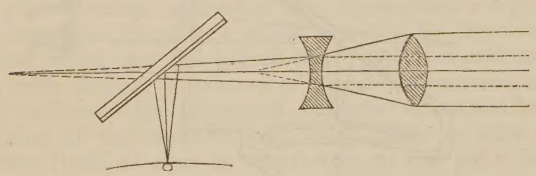
"To make a practical use of the level so arranged, we may either have it attached to the frame of the sextant, or have it on a stand in front of the sextant. *But in either case the bubble*

must be brought to its own fiducial mark at the instant of any observation.

"Herein is the first of our practical difficulties; for if the level be on a stand, and that on the ship's deck, the bubble is rolling from end to end of the tube with every roll of the ship; and if the apparatus be fastened to the sextant and held by hand, no man has power or tact to hold it level. Some natural principle must be brought in then to assist man's hand. And such a principle is found in the level-bubble itself, which will always be at the *summit of the arc*. If, therefore, we can refer our observations, not to the fiducial mark, but *to the bubble itself as it moves* apparently with the rolling of the ship, we shall be able to measure altitudes accurately at sea; and herein are the chief of my novelties.

"If we make the radius of curvature of the level, and the solar focus of the collimator equal, then if the whole is tilted one degree the bubble viewed in the diagonal mirror runs in the opposite direction to the same angular extent, by reason of the equality of the level radius, and the focal length of the collimator, or radius of the sphere on which the optical picture is formed.

"The result of these compensations is, that tilt the case of the level up or down by any quantity within the angular extent of the level tube, you will always see the bubble in the same true horizontal direction . . . . When carrying out the principle in practice, if (for example) the level is of 12 feet radius, a collimator 12 feet



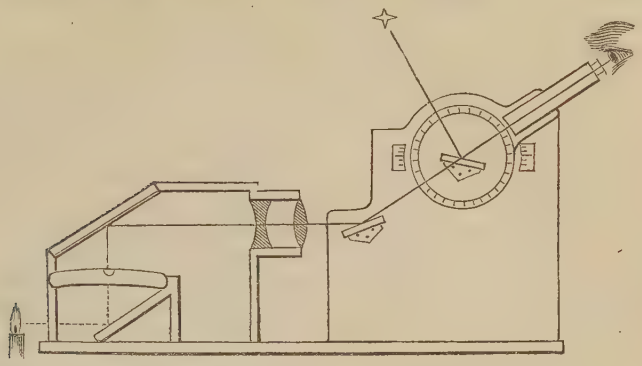
long would be an inconvenient appendage to a sextant; but the focus may then be lengthened virtually by inserting one or more *concave* lenses with a convex of much shorter focus.*

"Now put everything together; and for an observation, in place of the ordinary sextant, use my reflecting circle, the level being attached to the same stand.

"Looking into the telescope, you see the star in the upper mirror, which moves with the circle, and gives the angle moved through on the vernier. The lower mirror, fixed on the frame of the instrument, shows the bubble of the level, along with the star, in the telescope. The observer sees the bubble in the middle of the field, and the star in its centre. If the stand be tilted by a

* The form and construction of the level itself have been described with a figure. (*Ast. Soc. Notices*, xvii. 37, Dec. 1855.)

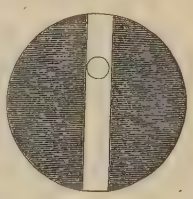
small angle, the star ascends or descends in the field, but so also by the same angle does the peculiar level bubble . . . . In other



words, though the field of view, and all fiducial marks of the telescope and the level-tube vary and err, yet the level-bubble always continues to show the true horizontal direction ; it preserves the same angular distance from the star, and all that we have to do in making an observation (no matter whether the base be quite level or not—and herein is the difference from the ordinary use of a level on land), is so to move the upper mirror of the circle as to make the star come on to the bubble, and then read off the verniers. Once on the bubble, the star will remain there as long as the support, or ship's deck, does not roll through a greater angle than the level tube comprises, or does not roll in a quick, jerking manner.

"For these larger deviations the principle of the stability of the free revolver must be applied, as elsewhere described. (See *Ast. Soc. Notices*, xvii. 40.)

"On looking into the collimator, all the transmitted light is blocked out, except the central line. This is to keep the field dark and appropriate for star-observations. The self-adjusting motions of the bubble then take place along the luminous lane, and laterally an approximate correction is shown by the approach of the bubble to one or the other side of the said lane."



The inventor also adds, with reference to the practical construction of the level :—

"Some practical men would exclaim on hearing of a level of one foot radius, that it must be so sluggish as to be good for nothing ; yet it is less sluggish ; and the nature of sluggishness in levels has been much misunderstood, viz. mixed up with amount of motion of the bubble as depending on length of radius of the tube.

"Make treacle the fluid of levels, and they will all be sluggish; long or short radii, *i. e.* after a certain angular tilt, the bubbles will be moving slowly for a long time before coming to their new point of rest.

"Put ether into a tube of long radius; it moves *quickly* in the above case from want of sluggish nature, and moves *far*, by reason of the long radius. Put ether into a tube of very short radius, men say how sluggish, because it does not move far, measured in the linear way. But they should rather ascertain which bubble comes to its new place of rest soonest; and if by reason of short radius they cannot easily see what arc one bubble moves through, they can increase the radius optically by magnifying. Now by mere optical magnifying, the bubble has no mechanical friction added to its motion; but if the magnifying be by increasing the radius of the level, the bubble has a greater mechanical task of walking along so much more in length of glass surface.

"Hence it may be shown that these new short-radius levels viewed through magnifiers, are as accurate, and quicker in their motions of *angle*, than the usual ones of long radii looked at with the naked eye.

"All fluids have more or less of the sluggishness or stickiness so greatly developed in treacle; alcohol has less than water; ether the Germans found to have less than alcohol; and chloroform I have found to have less than ether: while it has the great advantage (seeing that the end of tube must be hermetically sealed with a blow-pipe flame), over both ether and alcohol, of not being inflammable."

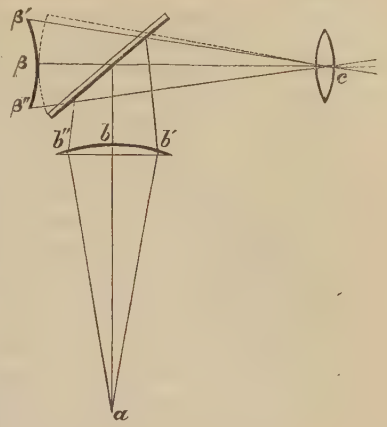
He also mentions that practically a good range of arc is 5°, and a good radius, 9 feet.

Note on the above Communication. By Rev. Baden Powell, M.A., F.R.S., &c., Savilian Professor of Geometry, Oxford.

Professor C. P. Smyth's new artificial horizon has been very briefly and generally described by him in communications to the Royal Scottish Society of Arts, to the Royal Astronomical Society (*Notices*, xvii. 37), and in the Descriptive Catalogue of the French Exhibition, 1855, where the instrument itself was seen. But no detailed account of the *principle* of the construction has appeared. The writer of this note having requested such an account from the inventor, has also obtained his consent to lay it before the Royal Astronomical Society, as its importance well deserves. But to render it complete, it appeared to him that a more precise elucidation of the *optical* principle involved was desirable; this may be most distinctly stated as follows:—

1. The tube of the spirit-level being a small arc of a circle of considerable radius, within the limits of this arc, the true horizontal line is the tangent to that point of the arc at which the

bubble appears; and in any successive positions, the change of inclination is measured by the angle of intersection of the tangents, which is the same as the arc of the tube traversed by the bubble, or the angle at the centre (a).



2. Taking the chord of this arc as the base, a plane mirror inclined at 45° to it above, gives for the reflected image of the level-tube a similar arc *convex* towards it.

3. A lens placed in front of the mirror, having its principal focal length equal to the distance of the image of the bubble when at the middle point of the arc, and adjusted to receive centrically the reflected diverging pencil from the bubble will cause it to emerge in a parallel pencil, thus placing the image at an infinite distance, and enabling us to view it through a telescope.

4. In other positions of the bubble (*since the convexity is towards the lens*), it will not be accurately in focus; though it will be approximately so if the focal length be considerable, so that the small difference in the length of the rays from the middle point, and from the two extremities, may be neglected.

5. If the base be accurately horizontal, and consequently the bubble (b), in the middle of the arc to which the index is adjusted, the axis of the reflected pencil from its image (β) passing through the centre of the lens (c), will be accurately horizontal; or the image seen through the lens gives the true horizontal point, this adjustment is supposed accurately made in the first instance once for all.

6. If the base (the lens and mirror being firmly attached to it), be inclined either way, within the limits of the arc, any change in the position of the bubble measured on the *arc* of the tube ($b'\,b''$), will be exactly equal to the change measured on the *arc* of the reflected image ($\beta'\,\beta''$).

7. If the focal length of the lens be equal to the radius of the arc of the level ($b\,a$), and if the distance were accurately the same from the lens (c) to all points of the reflected arc ($\beta'\beta''$) (as it would be if the image were *concave* towards the lens), then for any change of *arc* (as from β' to β'') there would be an exactly equal change of *angle* in the rays at (c), and as in the middle position the reflected ray ($\beta\,c$) is exactly horizontal, so in every other position would the reflected rays ($\beta' c$) ($\beta'' c$) for those positions respectively give the true horizontal point.

8. But since the image is *convex* towards (c), the angle at c

is (in strictness) less than the angle at *a*. Yet if the radius or focal length be large, and the arc small, the conditions will be so approximately fulfilled, that without sensible error, the change of *angle* will be equal to the change of *arc*, or of *inclination to the horizon*, and consequently *the reflected ray will give the true horizontal point without sensible error at all inclinations within the limits.*

Professor C. P. Smyth's invention becomes of peculiar value (in combination with his free-revolver stand), since the attainment of an artificial horizon on board ship has been in vain sought in any applications of the ordinary spirit-level, of liquid reflecting surfaces, by simple suspension in equilibrio, or by the rotating plane reflector of Troughton's top ; the failures of which are demonstrable on mechanical grounds.

But the invention may become of not less importance to observers on land, and especially to scientific travellers, from its portability and exemption from the disturbances incident to liquid reflectors.

Results of the Observations of Small Planets made at the Royal Observatory, Greenwich, from Dec. 4 to Dec. 31, 1857.

(*Communicated by the Astronomer Royal.*)

Metis.

Mean Solar Time of Observation.	Apparent R.A.	Apparent N.P.D.
h m s	h m s	° ′ ″
1857, Dec. 10 11 21 44·5	4 40 15·01	66 34 41·81
19 10 37 6·7	4 30 58·91	66 21 17·99

Hygeia.

Mean Solar Time of Observation.	Apparent R.A.	Apparent N.P.D.
h m s	h m s	° ′ ″
1857, Dec. 5 8 30 17·6	1 28 37·19	75 52 6·53
19 7 34 23·2	1 27 45·39	76 18 18·27

Irene.

Mean Solar Time of Observation.	Apparent R.A.	Apparent N.P.D.
h m s	h m s	° ′ ″
1857, Dec. 7 9 49 19·8	2 55 45·49	80 37 26·08
10 9 35 28·4	2 53 41·44	80 34 7·10

Calliope.

Mean Solar Time of Observation.	Apparent R.A.	Apparent N.P.D.
h m s	h m s	° ′ ″
1857, Dec. 7 12 11 46·7	5 18 35·84	62 3 41·05
19 11 11 49·1	5 5 47·07	61 16 26·47

Leucothea.

Mean Solar Time of Observation.	Apparent R.A.	Apparent N.P.D.
h m s	h m s	° ′ ″
1857, Dec. 5 7 14 40·3	0 12 47·51	84 29 42·69

Isis.

Mean Solar Time of Observation.	Apparent R.A.	Apparent N.P.D.
h m s	h m s	° ′ ″
1857, Dec. 7 12 1 17·0	5 8 4·41	68 51 11·77
19 11 0 41·2	4 54 37·30	68 31 22·79

The observations of N.P.D. have not been corrected for parallax.

Aglaia.

Mean Solar Time of Observation.	Apparent R.A.	Apparent N.P.D.
h m s	h m s	° ′ ″
1857, Dec. 10 6 27 52·2	23 45 34·45	90 3 52·01

Royal Observatory, Greenwich, 1858, *Jan.* 14.

On the relative Precision of Measures of Double Stars, taken Photographically, and by Direct Vision. By G. P. Bond, Esq.

(*Communicated by Mr. Carrington.*)

"An examination of a large number of photographs of *Mizar*, eighty-six in all, taken between May and August last, by Messrs. Whipple and Black at this Observatory, has brought out some interesting facts respecting the precision of this new method of observing double stars.

"Employing an achromatic reading microscope, moved horizontally by means of a micrometer screw, the bisections of the images are made with an exactness quite surprising, considering their indefinite outline and comparatively large diameter. In the course of the examination above seven hundred bisections were

made upon the different images. Of these but a single one showed a discrepancy from the mean of the set to which it belonged, exceeding *two-tenths* of a second of arc. The probable sum of the errors of the two bisections necessary for a single measure of distance, is $\pm$ 0″·046.

"The probable error of the distance of the centres of the photographs of *Mizar*, and its companion, is $\pm$ 0″·072, for a single pair of images, formed by exposures of between 9^s and 40^s. The probable error of a single micrometer measurement of a double star of this class, taken in the ordinary way, is $\pm$ 0″·127; so that the relative value of the photograph is $\left(\frac{0''\cdot127}{0''\cdot072}\right)^2$; or the photograph is worth *three times* as much as a single direct measure. I shall take another opportunity of communicating the details of the discussion upon which these conclusions are based.

"*Observatory of Harvard College, Dec.* 29, 1857."

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*Miscellaneous Notes.** By the Rev. W. R. Dawes.

Observation of a Spot in Saturn.

"I have lately observed a well-marked light spot on the southern hemisphere of *Saturn*, which I estimated to be at about 40° or 45° of south latitude. It was nearly in the axial line on Jan. 11th, at $10^h\ 30^m$ G. M. T., and again on Jan. 14th, at $11^h\ 20^m$; on both occasions a little past it. As distinctly visible phenomena of that kind on *Saturn* are not of very frequent occurrence, perhaps it might be desirable to mention it in the forthcoming Notices."

Observations of the Satellite of Neptune.

"I have obtained two indubitable observations of the satellite of *Neptune* with my 8-inch object-glass; one on Dec 4th, at $6^h\ 52^m$ G. M. T., when it was near its eastern elongation, and the other on Dec. 11th, at $7^h\ 0^m$, when it was nearly on the opposite side. It was more decidedly visible than I should have expected."

Further Observations of the Bright Spots on Jupiter.

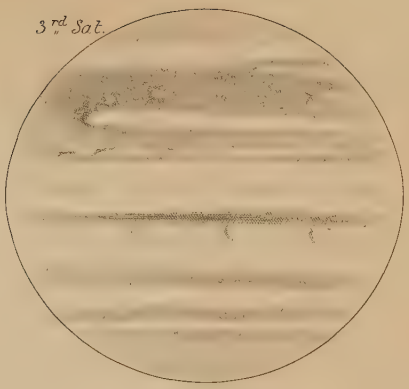
"'1857, Dec. 11; $4^h\ 44^m$ G.M.T. There is an *irregular very dark spot* on the south polar cap, near its northern edge.

"'Some of the round bright spots are visible on the second southern belt; but they have been carried too far by the rotation of the planet for the whole group to be seen.'

"'$5^h\ 2^m$ G.M.T. The second spot from the eastern limb is in the axial line. The sketch (No. 5) shows the appearances *at this time*. The irregular *dark* spot on the southern polar cap has changed to a *bright* one, and is, no doubt, a satellite transiting: from its situation it must be the *third*.'

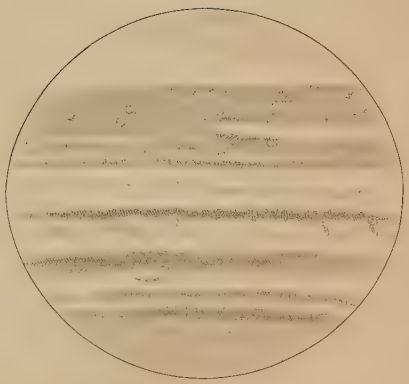
* The first two of these notes are extracted from a letter to the Editor; the third is an extract from Mr. Dawes' journal, and is a continuation of the observations of *Jupiter's* spots from the *Monthly Notices* of December, page 50.

5



1857 Decr. 11.
at 5h. 2m. G.M.T.

6



1857 Decr. 19.
at 10h. 30m. G.M.T.

W. R. D. del.t

J. Basire, sc.

"When near the limb, the satellite had very much the appearance of one of the round bright spots, and afforded a good scale for comparison. The diameter of the largest of the spots was judged to be about *two thirds* of the diameter of the satellite.

"'$5^h\ 34^m$ G.M.T. The eastern spot is nearly in the axis. This spot looks rather less neatly defined than the rest, especially on the eastern side of it.'

"'Dec. 19; $10^h\ 30^m$ G.M.T. The western end of the bright streak between the southern equatoreal belt and the second belt is now about in the axis. The sketch (No. 6) represents the aspect of the planet at this time. The positions of the bright spots have varied considerably, with reference both to the bright streak and to each other. There are two little bright spots at the northern side of the bright streak; but they have not quite the same appearance as those on the south side, and when best seen look *oval* in the direction of the belts.'

"*Haddenham, Thame,*
"1857 *Dec.* 29."

Annular Eclipse of the Sun, 1858, *March*, 14–15.

The various circumstances of this eclipse, calculated from the tables of the sun and moon, hitherto employed in the preparation of the *Nautical Almanac*, are given in the volume of that Ephemeris for the current year. The following new determination of the path, described by the central point of the eclipse, in the course of its passage over England, calculated from Hansen's Lunar Tables and the Solar Tables of Hansen and Olufsen, has been recently published by Mr. Hind.

Path of Central Line across England.

G. M. T.	Longitude.		Latitude.		Duration of Annulus.
d h m s	° ′ ″	″	° ′ ″	″	s
Mar. 15 0 55 0	W. 3 53 20	5 23	N. 49 59 46	+4 12	8·7
10	3 47 57	5 25	50 3 58	4 12	8·8
20	3 42 32	5 26	50 8 10	4 13	8·9
30	3 37 6	5 28	50 12 23	4 12	9·0
40	3 31 38	5 29	50 16 35	4 13	9·1
50	3 26 9	5 31	50 20 48	4 14	9·2
0 56 0	3 20 38	5 33	50 25 2	4 15	9·3
10	3 15 5	5 34	50 29 17	4 15	9·4
20	3 9 31	5 37	50 33 32	4 16	9·5
30	3 3 54	5 38	50 37 48	4 17	9·6
40	2 58 16	5 40	50 42 5	4 16	9·7
50	2 52 35		50 46 21		9·8

G. M. T. d h m s	Longitude. ° ′ ″	′ ″	Latitude. ° ′ ″	′ ″	Duration of Annulus. s
Mar. 15 0 56 50	W. 2 52 35	5 42	N. 50 46 21	4 17	9·8
0 57 0	2 46 54	5 43	50 50 38	4 17	9·9
10	2 41 11	5 45	50 54 55	4 17	10·0
20	2 35 26	5 47	50 59 12	4 17	10·1
30	2 29 39	5 49	51 3 29	4 17	10·2
40	2 23 50	5 51	51 7 46	4 18	10·3
50	2 17 59	5 53	51 12 4	4 18	10·4
0 58 0	2 12 6	5 54	51 16 22	4 18	10·5
10	2 6 12	5 57	51 20 40	4 18	10·6
20	2 0 15	5 58	51 24 58	4 19	10·7
30	1 54 17	6 1	51 29 17	4 19	10·8
40	1 48 16	6 3	51 33 36	4 20	10·9
50	1 42 13	6 5	51 37 56	4 20	11·0
0 59 0	1 36 8	6 8	51 42 16	4 22	11·1
10	1 30 0	6 9	51 46 38	4 22	11·2
20	1 23 51	6 12	51 51 0	4 23	11·3
30	1 17 39	6 14	51 55 23	4 24	11·4
40	1 11 25	6 16	51 59 47	4 25	11·5
50	1 5 9	6 19	52 4 12	4 26	11·6
1 0 0	0 58 50	6 21	52 8 38	4 27	11·7
10	0 52 29	6 23	52 13 5	4 28	11·8
20	0 46 6	6 25	52 17 33	4 29	11·9
30	0 39 41	6 28	52 22 2	4 29	12·0
40	0 33 13	6 30	52 26 31	4 30	12·1
50	0 26 43	6 32	52 31 1	4 31	12·2
1 1 0	0 20 11	6 35	52 35 32	4 31	12·3
10	0 13 36	6 37	52 40 3	4 32	12·4
20	0 6 59	6 40	52 44 35	4 33	12·5
30	W. 0 0 19	6 42	52 49 8	4 33	12·6
40	E. 0 6 23	6 45	52 53 41	4 33	12·7
50	0 13 8	6 47	52 58 14	4 34	12·8
1 2 0	0 19 55	6 49	53 2 48	4 33	12·9
10	0 26 44	6 52	53 7 21	4 34	13·0
20	0 33 36	6 55	53 11 55	4 34	13·1
30	0 40 31	6 57	53 16 29	4 35	13·2
40	0 47 28	7 1	53 21 4	4 35	13·3
50	0 54 29	7 3	53 25 39	4 36	13·4
1 3 0	E. 1 1 32		N. 53 30 15		13·5

As there appears to be a considerable degree of uncertainty

with regard to the precise diameters of the sun and moon, which should be employed in the calculation of eclipses, no change has been made in the column headed "Duration of Annulus," which is merely an extension of that given at p. 467 of the *Nautical Almanac* for 1858. The diameters there introduced indicate nine miles as the mean breadth of the annular belt in this country.

The same circular contains equations of reduction for Liverpool, Durham, Bristol, and Exeter; they are similar to those for Greenwich, Cambridge, Oxford, Edinburgh, and Dublin, already published in the *Nautical Almanac* for 1858, and are founded upon the same elements.

Observations on the Planet Saturn, made with the Twenty-three Foot Equatoreal at the Observatory of Harvard College, 1847–1857.* By William Cranch Bond, A.M., &c., Director of the Observatory, Cambridge, U.S., 1857.

These observations extend over the period included between the disappearance of the ring of *Saturn* in 1848, when its plane passed through the Sun and Earth respectively, and its greatest opening in 1856. They might, consequently, be expected to possess considerable interest in regard to the light which they are calculated to throw upon the physical structure of the mysterious appendage by which the planet is surrounded. Mr. Bond states that the principal object which he had in view when he first commenced his observations, was to collect additional facts relative to "the bright spots or prominences and interruptions seen upon the ring at the time of its so-called 'disappearance.'" The results of a careful examination of the planet on that occasion were found to possess sufficient interest to justify him in prolonging the period of the observations beyond the limit within which he originally proposed to confine them.

The author gives the following statement of the most prominent subjects noticed in his paper:—

1st. The numerous observations made upon the interruptions and points of light seen on the ring at or near the time of the passage of its plane through the Sun and Earth.

2d. The determination of the times of disappearance and reappearance of the ring.

3d. Observations upon the distances and relative brightness of the satellites.

4th. The discovery of the eighth satellite *Hyperion*.

5th. The discovery of the new ring.

6th. Observations of extraordinary subdivisions in the rings, and of shadings and other peculiarities upon the rings and ball.

* Annals of the Astronomical Observatory of Harvard College, Vol. II. Part I.

7th. Observations for determining the relative proportions of the rings and ball.

8th. Observations upon the form of the shadow and of the encroachment of the ball upon the ring.

The observations were made with the great refractor of 15 inches aperture.

The observers were — Mr. W. C. Bond, the Director of the Observatory, Mr. G. P. Bond, Mr. C. W. Tuttle, and Mr. Sidney Coolidge.

The paper commences with a journal of the observations, extending from August 27, 1847, to April 5, 1856, in which we find recorded a multitude of interesting remarks relative to the physical phenomena exhibited by the Saturnian system during the intervening period. This part of the paper also contains the original observations, which led to the discovery of the eighth satellite, *Hyperion*, and the dusky ring of the planet. The remaining part is devoted to an investigation of the results deducible from the observations.

After an investigation of the dimensions of the planet and rings, the author next proceeds to consider the circumstances attending the disappearance of the ring. He notices the important fact, " that for the whole time during which the Sun and Earth occupied opposite sides of the ring, a certain amount of light was always seen to proceed from the ring sufficient at least to render it visible with the great refractor." Sir William Herschel, who had observed the ring under similar circumstances, suggested whether the phenomenon might not be attributed to the light reflected by the rounded edge of the ring, or to the reflexion of the light of the planet on the dark side of the ring. The former of these hypotheses does not seem probable when the excessive thinness of the ring is taken into consideration.

With regard to the latter, the author concludes, from an investigation of the circumstances of the case, that it is totally inadequate to account for the phenomenon.

It has been suggested whether the appearance presented by the unilluminated side of the ring, when the sun was depressed below its plane, might not be attributed to the effect of a twilight caused by the existence of an atmosphere around the ring. The author, however, shows that the observations are inconsistent with this explanation; for at the time when the twilight ought to have been strongest, the light of the ring was faintest, and *vice versâ*. In reference to this hypothesis, the author further remarks:—

" We may add to these arguments against the probability that twilight alone sufficiently explains the visibility of the ring on the dark side, that the light proceeding from it does not exhibit the uniform greyish cast characteristic of our twilight, but is unevenly broken and interrupted, in some parts shining with a clear, and almost sparkling, lustre, in intrinsic brightness frequently equal to that of the satellites illuminated by direct sunlight.

"Finally, by twilight those parts of the ring should reflect back to the earth most light, which present to it the greatest apparent area of surface. This illumination should, then, be most sensible on each side of the ball, between the points corresponding to the inner and outer edges of the [middle] ring B. According to the observations, this, instead of being the brightest, was, on the contrary, decidedly the faintest portion of the whole ring."

From the question of the visibility of the dark side of the ring, the author passes to a consideration of the bright prominences and inequalities of light noticed on the ring. These luminous points resembled satellites in lustre, having been in many instances distinguishable from them only by the peculiarity of their maintaining a fixed position relatively to the ball. Thus, on the 11th of July, 1848, for an interval of more than two hours, the motions of the satellites "were very evident, but the bright spots on the ring did not change their positions." July 18, during one hour's watching, "the inequalities had undergone no change." July 21, during two hours, "neither point showed any motion."

The author further remarks that the evidence of the stability of the luminous prominences, not only from hour to hour but for months in succession, was most conclusive.

"The brighter portions, when best seen, resembled elongated beads or globules upon a thread of light. The line of light was at such times continuous from the ball to the outer edge of the outer ring, but very faint in some parts. The brighter parts were four in number, symmetrically placed, two on each side of the ball, the two outer separated from the inner by an interval through which an exceedingly faint thread of light could be traced. Between the ball and the inner points, the light was more conspicuous than in the interval between them and the outer points."

"Under inferior definition the details of these features were lost to the eye, but the general impression remained of a line of light broken up into brighter and fainter portions. This line, and especially the prominences, were remarked in July [1848] to be sensibly above the projection of the ring and its shadow on the ball; but in October and November to be below it."

The author endeavours to show that the phenomena may be adequately explained by the reflexion of the sun's rays from the edges of the different rings, and perhaps in part also by the transmission of the light through the substance of the dusky ring.

The theoretical part of the paper concludes with an investigation of the thickness of the ring, which the author finds to be forty miles. From this result, adopting Bessel's value of the mass of the ring, viz. $\frac{1}{119}$, he determines the density of the ring to be three times the density of the planet. If a smaller value of the thickness of the ring be adopted the density would of course be proportionally increased.

Appended to the paper is a series of observations of the planet extending from January 13, 1857, to the time of going to press

(April 25, 1857). The object which the author had in view in executing these observations was to collect materials "for clearing up the mysterious phenomena of the shadows cast by the ball upon the rings."

These observations are followed by a large collection of wood-engravings of the various appearances presented by the Saturnian system during the period to which the totality of the observations recorded in the paper refer.

Among the works presented to the Society and laid on the table at their last evening meeting, was one to which the attention of the Fellows may be particularly called, namely, M. Julius Schmidt's *Resultate aus eilfährigen Beobachtungen der Sonnenflecken*. For many years M. Schmidt was in the habit of annually contributing to Prof. Schumacher's *Nachrichten* short summaries of his enumerations not materially differing from those of the Hofrath Schwabe, which have recently attracted the especial regard of astronomers, and in particular of this Society. So far M. Schmidt's observations served as a valuable independent corroboration of the periodicity established by M. Schwabe. In the publication here noticed M. Schmidt collects together such results and remarks from his day-books as came under his observation during the years 1841 to 1852; since which date he has resigned the subject from a consideration that others, and in particular Prof. Wolf, were paying it sufficient and more consecutive regard. M. Schmidt's observations have consisted partly in enumerations of abundance or paucity, partly in physical remarks or critical features, partly in careful delineations of figures of remarkable spots, made at different places, and with such instruments as his opportunities placed at his disposal. At two of these places, Hamburg and Bonn, he had the advantage of employing telescopes of considerable power and excellence; and it is to the admirable drawings, lithographed with no less excellence, selected for publication out of his own more extensive collection, that it is the object of the writer* on this occasion to call attention. He believes that no observer will examine these delineations without finding many characteristic features not satisfactorily explained by any existing theory of the origin and formation of the spots, and without a conviction of the necessity of accumulating other equally excellent series for the future establishment of correct views of this mysterious phenomenon. The writer could name more than one Fellow of this Society possessed of the peculiar artistic talent required for the successful delineation of such forms, who would render astronomy good service by devoting a portion of his time to this work. Very little trial will convince an observer, that till photography lends her aid, training of the hand

* The Editor is indebted to Mr. Carrington for this notice of M. Schmidt's labours.

and eye is no less required in this matter than for a professed artist to establish a reputation for portrait-painting or the representation of the various attitudes of animal life. M. Schmidt's drawings are singularly successful in this respect, and the writer is especially gratified by perceiving the minuteness and care with which he has introduced the little outlying dots which many might omit or think of slight importance. One omission he notices, that of the scale of the drawings, which other observers will do well to introduce.

It is probably not very generally known at present that the talented Parisian artist M. Porro has turned his attention with success to the construction of a helioscope with which the sun may be viewed directly without the interposition of coloured glasses, even with considerable apertures. M. Porro has given the telescope the Newtonian form, with an adaptation of the mirror, by which only a few hundredths of the incident light and heat are reflected, and finally obtained an almost total extinction of the remaining heat-rays by a second modification of the deflecting prism. His price, moreover, is very considerably less (one third to one fourth) than that of an achromatic refractor of the same aperture.

Tables de la Lune construites d'après le Principe Newtonien de la Gravitation Universelle. Par P. A. Hansen, Directeur de l'Observatoire Ducal de Gotha. Imprimé aux frais du Gouvernement Britannique. 4to. London, 1857.

These Tables are founded upon the elements of the moon's motion, given by Professor Hansen in the *Monthly Notices* for November 1854. Before proceeding to give some account of their construction, it will be desirable to explain briefly the theory by the aid of which the expressions for the moon's co-ordinates have been obtained, and for which astronomy is indebted to Professor Hansen.

Let g denote the mean anomaly of the moon, f the true anomaly, L the true longitude, e the excentricity of the orbit, Π the longitude of the perigee, r'' the number of seconds contained in the arc whose length is equal to the radius, and P the sum of the perturbations of the true longitude; further let us suppose that the moon revolves in the plane of the ecliptic. We have then according to the ordinary theory of the moon's motion:—

$$f = g + r''\left(2e - \frac{1}{4}e^3 + \frac{5}{96}e^5\right)\sin g$$
$$+ r''\left(\frac{5}{4}e^2 - \frac{11}{24}e^4 + \frac{17}{192}e^6\right)\sin 2g$$
$$+ r''\left(\frac{13}{12}e^3 - \frac{43}{64}e^5\right)\sin 3g + \ldots.$$
$$\mathrm{L} = f + \Pi + \mathrm{P}$$

It has been shown, on a former occasion, that as the lunar theory advanced towards perfection the number of terms represented by P continued to increase until at length in the American Tables, constructed mainly upon Plana's theory, the number of arguments in the true longitude amounted to about 80.* According to the theory which forms the basis of Professor Hansen's Tables, the quantity P does not appear in a separate form in the expression for the true longitude, but enters into combination with f by means of a corresponding change perpetually affecting the value of g. Let $f + \mathrm{P} = f'$, and let $n\,z\,(= g + n\,\delta z)$ be the value of g, which would result upon substituting f' for f in the above expression for the true anomaly, n being the mean daily motion of the moon. We have then—

$$\mathrm{L} = f' + \Pi$$

f' being the true anomaly corresponding to the quantity $n\,z$ which has replaced the mean anomaly g.

Let us now take into consideration the inclination of the lunar orbit to the ecliptic. Let R represent the reduction to the ecliptic, R′ the inequalities of the reduction, including the solar and lunar nutations. We have then

$$\mathrm{L} = f' + \Pi + \mathrm{R} + \mathrm{R}'$$

and it is plain that corresponding expressions involving $n\,z$ may be obtained for the parallax and latitude.

It will be seen from the foregoing brief explanation that in Professor Hansen's theory, the effects of perturbation are thrown entirely upon the mean anomaly in so far as it is a function of the time. In the expression which he has given for $n\,\delta z$ representing the inequalities of $n\,z$ the number of terms amounts to 202. Of these he has omitted 68 in the construction of the Tables in consequence of the extremely small effect which would be produced by their aggregate value.

The inequalities of $n\,z$, amounting in number to 134, are grouped as much as possible, and arranged in tables, partly of single, and partly of double entry. In the formation of the tables of the latter class, Professor Hansen has employed a peculiar artifice, which will be best explained in his own words :—

"Let us consider," says he, "a certain number of terms of the following form which is the form of the lunar inequalities :

$$\begin{aligned}
&\&c \\
+ - \; & a_{-1} \sin(-g + \mathrm{A}) \\
+ \; & a_0 \sin(\quad\; \mathrm{A}) \\
+ \; & a_1 \sin(g + \mathrm{A}) \\
+ \; & a_2 \sin(2g + \mathrm{A}) \\
+ \; & \&c
\end{aligned}$$

* *Monthly Notices*, vol. xiv. p. 28.

g being the mean anomaly of the moon, and A the second argument composed of other quantities. Making

$$f \sin F = - \&c - a_{-1} \sin g + a_1 \sin g + a_2 \sin 2g + \&c.$$
$$f \cos F = \&c + a_{-1} \cos g + a_0 + a_1 \cos g + a_2 \cos 2g + \&c.$$

the sum of the foregoing terms becomes

$$= f \sin (A + F)$$

If then we calculate first a series of values of f and F, for a series of values of g, distributed equally over the whole circumference, and afterwards a series of values of $f \sin (A + F)$ for corresponding values of A, we shall have reduced these terms into tables of double entry. But according to this mode of procedure, the argument A varies proportionally to the time, and for each place of the moon to be calculated it would be necessary to form a fresh value of A. This complicated process may be avoided, and the argument A may be rendered constant throughout each entire period of g by adding to each of the various values of F, the movement of A from $g = 0$ to the value of g, which corresponds to the given value of F. In this way the value of A to be employed in finding the inequalities of the table is that which corresponds to the instant when $g = 0$, and only when a new period of g has commenced will it be necessary to employ another value of A, which in its turn corresponds to the zero value of g in the new period."

By employing this process in every practicable instance, Professor Hansen is enabled to arrange the inequalities affecting the mean anomaly in a series of tables, of which thirty are tables of double entry depending on twenty-seven distinct arguments, and twenty-three are tables of single entry adapted to an equal number of arguments. The aggregate number of tables amounts therefore to fifty-three; and the aggregate number of arguments, whether simple or compound, to fifty.* A similar mode of grouping is employed in the formation of the tables of parallax and latitude.

The successive values of the various arguments, with the exception of those representing the argument A, in the tables of double entry are expressed in mean solar days. This practice, originally recommended by Carlini, has been already employed in the construction of the American lunar tables.

The tabular values of g are expressed in days to the seventh decimal figure. The co-efficients of the various inequalities of g, originally expressed in seconds of space, are also converted into time; but the necessity of using a multitude of zeros is dispensed with by expressing them in terms of the seventh decimal of the day assumed as the unit. Accordingly the tabular values both of the arguments and the inequalities of $n\,z$ are expressed in time.

It has been stated that in the tables of double entry one of the arguments is g, and that the second argument A is composed

* A few additional tables are required for computing the true longitude.

of other elements. In the latter case the combination of elements varies of course from one table to another. The values of g, for which each inequality is computed, head the table in a horizontal column; the corresponding values of the second argument are arranged in a vertical column at the margin. The inequalities are computed for every six hours of g, extending from $g = 0^{d}.25$ to $g = 29^{d}.75$, or somewhat more than a period; and for successive values of each vertical argument differing by a unit of its respective period.* In computing the moon's place for a given date the value of each inequality corresponding to its vertical argument is readily found by a process of simple interpolation, the differences of the successive numbers in the vertical columns being in all cases very small. In so far as the inequalities depend upon the horizontal argument g, the process for finding their values is different; for since they must all be determined for the *same value* of the argument, namely, that for which the moon's place is to be calculated, it suffices to take from the tables two values of each inequality corresponding to two values of g, one greater and the other less than the given argument, and then to interpolate once for all between the sums of the results.

It is only the smaller inequalities which are arranged in tables of double entry. In the case of inequalities of considerable magnitude, it would be necessary to give the tables an enormous extension in order that the differences of the successive numbers in the vertical columns might be sufficiently small to admit of easy interpolation.

In the tables of single entry the successive values of the arguments differ by the hundredth of a day, and the inequalities are accompanied by columns of differences to facilitate interpolation. In every case the tables are computed for a period of the inequality plus an anomalistic month. This arrangement affords great advantage in the computation of an ephemeris of the moon's place.

Since the sines recur in regard both to quantity and direction, in the first and second, and again in the third and fourth quadrants; and since the cosines similarly recur in the first and fourth, and in the second and third quadrants, the tables, in most cases, admit of being reduced to half the extent they would otherwise occupy.

When the inequalities represented by δz† are computed by the tables and added to g (expressed in time), the result constitutes z, upon which depend the true longitude, parallax, and latitude. This quantity is termed by Professor Hansen *the fundamental argument.*

The following is the mode of computing the values of the arguments. The example is taken from the Introduction to the Tables:

* The unit of the period is different for each vertical argument, being manifestly chosen so that for the successive values of the argument, the differences of the numbers in the vertical columns may be of inconsiderable amount.

† nz and $n\delta z$ are represented in time by z and δz.

Let us suppose the date to be

1761, Feb. 2, $4^h\ 4^m\ 4^s.4$ G.M.T.

By Tables I. and II. this date is equivalent to

$1761 + 33^d.1694954$ or 1761·090

Fundamental Argument.

Table.		*g*	I
		33·1694954	
III.	1700	13·3348081	69·757
IV.	61	11·8127793	0·546
			10·863
V.	2 per.	−55·1091026	−72·
		3·2079802	9·166

The column headed *g* does not require explanation. The fourth column exhibits the mode of computing one of the vertical arguments in the tables of double entry. The two first numbers in the column refer to the century and year. The third number exhibits the quantity to be added to the argument in consequence of *g* having completed two periods subsequently to the date (1761·0) for which it is in the first instance computed, for at the beginning of every new period the vertical argument must receive a new accession amounting to 5·432. The fourth number represents the period of the inequality corresponding to the argument. The anomalistic age of the moon for the given date is little more than three days. Now if the moon's place were to be calculated throughout the whole anomalistic month, the horizontal argument *g* would, of course, vary from day to day; but the vertical argument would remain constantly equal to 9·166, and it would be only when a new month commenced that the vertical argument would receive a fresh accession of 5·432, and would consequently become equal to 16·296, a value which it would continue to retain throughout the whole of the month, and so on similarly for each succeeding month.

The arguments in the tables of single entry are found in the same way as *g*. First, the argument is ascertained for the beginning of the century, then for the beginning of the year in the century, and, lastly, underneath these values is placed the number of days of the current year which has elapsed, a number which is manifestly the same for all the tables. These three numbers being added together, their sum diminished by the greatest multiple of an entire period contained in it constitutes the value of the argument for the date.

Professor Hansen remarks that when the place of the moon is calculated by the tables for every twelve hours, her place for any intervening period may be determined with equal accuracy by a

process of interpolation. To facilitate this object he has given tables of interpolation founded upon Stirling's Theorem. Tables are also given for converting longitudes and latitudes into right ascensions and north-polar distances, and *vice versâ*.

Astronomers cannot fail to look forward with interest to the publication of the theory upon which these tables are founded. In the meantime, it is impossible to contemplate without admiration the consummate skill with which the results of so vast a subject have been adapted to the computation of the moon's place. An illustration of the satisfactory accordance which exists between the results of some of the best modern observations of the moon, and the corresponding places in these tables, has already appeared in the *Monthly Notices* for November, 1854.

Mr. Pogson has forwarded an Ephemeris of the Variable Stars for 1858, which will be inserted in the *Monthly Notices* for March.

ERRATA.

Vol. XVIII., page 1, line 5 from bottom, *for* 0·28443 *read* 0·028443.

In the annexed engraving of *Jupiter*, *for* Vol. XVIII. No. 2, *read* Vol. XVIII. No. 3.

Mr. Drach has also forwarded the following Errata which he found in his transcript of Dr. Donati's letter respecting Comet VI., 1857 :—

Vol. XVIII., page 14, line 7 from the bottom, *for* −1 21·99 *read* −1 21·97

— , — — — *for* −1 18·14 *read* −1 8·14

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